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ANALYSIS OF GUNNERY DATA

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Abstract

Data from the gunnery Table VIII exercises in the M1A2 test at Fort Hunter Liggett were used to obtain maximum likelihood estimates of the parameters in a bivariate normal distribution of impacts of tank main gun rounds. The data are censored; impact position information is known only for rounds that hit the target panels. It is argued that much useful information was gained by observing impact position data, rather than recording only hit-miss data.

Key Words

Field Testing
Tank Gunnery
Censored Data
Gross Errors

1. Introduction

The problem facing us is the following. In operational testing of military equipment, there is a tendency to specify data requirements in terms that are readily collectable in a field testing environment. Many such data requirements are expressed in terms of pass-fail, yes-no and hit-miss. While these appear to be objective and not subject to interpretation, they almost always involve either a significant amount of subjectivity relative to the standards imposed and the quality of performance, or in the case of hit-miss, they may ignore readily available information that could provide valuable insight into the operational performance of the equipment being tested.

The case at hand involves the early user testing of the M1A2 tank conducted by the TEXCOM Experimentation Center at Fort Hunter Liggett, California in 1991. A comparison was to be made between the live fire performance of the M1A1 and the M1A2 model tanks in tank gunnery Table VIII and Table XII exercises. These Tank Tables are "standard" training type engagements where performance is measured by the successful engagement, i.e., hit, of a target and whether the hit occurred within the allowable time. We will only discuss data derived from Table VIII in which a single firing tank engages a combination of moving and stationary targets at various ranges.

An argument was made that more complete information could be obtained from each engagement that would allow a more precise

comparison of the performance differences between the two tanks. In addition to collecting only hit-miss information, we also measured the impact location of each hit relative to the center of the exposed target. The goal was to be able to estimate the delivery accuracy for conditions and ranges other than those specifically included within this test. An unknown at the beginning was the proportion of rounds fired that would actually hit the target and thus provide miss distance information useful in estimating parameters of the entire distribution.

Earlier testing of tank gunner performance [Glumm, West and Lee, 1982] and [West and Anstice, 1982] has shown that errors in azimuth and elevation can reasonably be treated as being normally distributed with a zero mean error about the center of the target as perceived by the gunner. These findings were obtained with complete data on aim error, tracking rate error and the resultant miss distance.

In this case, since a significant proportion (about 30%) of the rounds fired missed the target, the gunnery data under consideration are <u>censored</u>; the hit data can be considered as having come from a <u>truncated</u> distribution. (As we discuss below, the hit data are actually from a mixture of truncated distributions, due to the variations in ranges at which hits occurred and variations in target sizes.) The general terminology and basic analysis ideas associated with censored samples are reviewed (in a reliability and life-testing context)

by Kotz and Johnson [1982].

The relationships between the mean and variance of a truncated normal(μ,σ^2) distribution (caused by eliminating all observations outside an interval (A,B)) and μ and σ^2, is discussed by Johnson and Kotz [1970]. In particular, the mean of the truncated random variable is of the form $\mu+c\sigma$ and the standard deviation of the truncated random variable is of the form $c'\sigma$. The point is that in the gunnery application,

* the sample mean of hit data may appear to show bias even though theoretically the non-truncated random vector is unbiased; and
* the sample standard deviation of hit data may over- or under-estimate the true underlying (theoretical, non-truncated) standard deviation.

In our application there are many truncation points related to the various target sizes. In addition, the effects of ranges of engagement should be taken into account in an analysis of gunnery data, in order to provide constant variances. This can be done by transforming data to a "standard reference range." As the range of engagement varies, the apparent truncation points related to target boundaries vary, viewed from the perspective of a standard reference range. For example, the overall mean range of engagements for the data considered here is just under 1240 meters. In our analysis we consider the "effective" target sizes and miss distances at a standard reference range of 1240m. This

is accomplished by a simple transformation based on geometric similarity. For example, a miss distance of 50cm in the X direction for a shot at 1500m is equivalent to a miss distance of $50 \cdot 1240/1500 = 41.33$cm at the standard reference range.

Since the ranges at engagement varied from shot to shot over the data set, the effective target sizes at the standard reference range vary from shot to shot, even for the same type target. In statistical terms, the transformed gunnery data have (approximately) constant variances in each direction (X and Y) but they have a different set of truncation points for each shot. This complicates estimation of the mean and variance of the non-truncated gunnery miss distribution. We used a maximum likelihood estimation (MLE) approach for estimating the four parameters μ_X, σ^2_X, μ_Y, and σ^2_Y (all for the theoretical, non-truncated gunnery distributions), under various conditions involving the weapons and targets. A general approach for obtaining maximum likelihood estimates with censored samples is discussed by Kendall and Stuart [1979]. In general, it is not possible to obtain analytical expressions for the estimators for this case, and numerical optimization methods must be used for each specific data set.

We have obtained some interesting preliminary results with this approach. It should be noted that most of the results we report here could not have been obtained with only a hit-miss record for each shot; the measured X and Y miss distances, for

shots that hit the targets, contain much information about the gunnery process that simply is not contained in hit-miss data.

Our major conclusions are as follows:

* The dispersion in miss distance is about the same for both weapon systems in the X direction and in the Y direction.

* Both of the weapon systems were slightly left-biased in the X direction, and both were biased high in the Y direction.

* Approximately 90% of the misses were due to misses in the Y direction (and about 80% of these were shots over the target).

* There were no significant differences between the weapons systems, in terms of ranges of engagements, miss distributions, and hit probabilities. There is, however, a significant interaction between weapon system and target type and motion.

* There were significant differences in the miss distances (conditionally, given target hit) with respect to

  - phase,
  - light level,
  - vehicle × target type.

* There were significant differences in the ranges at engagement with respect to

  - phase,
  - light level,

- weapon system motion,
- target type, and
- vehicle × target motion.

* There is circumstantial evidence that a non-negligible fraction of misses (perhaps on the order of 5%-10%) were caused by gross errors not related to the gunnery distribution governing the X and Y miss distances for "typical" shots.

The findings of no significant difference between vehicles is logically supported by the minimal engineering differences between the fire control systems (FCS) of the two tanks. They both use the same gun tube and fire the same ammunition. The M1A1 FCS uses a gun director stabilization in elevation, i.e., the optics are stabilized in elevation and the gun is slaved to the optics and a disturbed sight reticle in azimuth, where the gun tube is stablized and the optics are tied to the tube. The M1A2 tank FCC uses a two axis stabilized optical system, i.e., a gun director in both axes. The M1A2 tank also has a slightly shorter smoothing time constant for use in calculating the lead angle to be applied to moving targets (0.6 seconds v. about 0.8 seconds). These changes would primarily affect performance on evasively moving targets. In this test all moving targets were of constant velocity.

Analysis of Gunnery Data

2. The Data

The data used in this analysis consists of information on 363 engagements occurring in Table 8 trials. Not all of the engagement records could be used, due to missing information on engagement range or other factors such as target type. Approximately 334 engagement records had information sufficiently complete for our use. We use the following labels throughout:

PHASE = phase of the table 8 trials

VEH = firing vehicle type

DN = light level (day, night)

ASMT = assessment of engagement results (hit, miss)

VEHMOT = firing vehicle motion (moving, stationary)

TGTMOT = target motion

CDR = commander ID

GNR = gunner ID

X, Y = impact distance from target centroid (cm) in horizontal (X) and vertical (Y) directions

XS, YS = impact distances, transformed to the standard reference range (1240 m)

RS = radial miss distance (given target hit), transformed to the standard reference range

RNG = range at engagement (m)

TGT = target (BFL = BMP flank, BFR = BMP front, TFL = Tank flank, and TFR = Tank front)

TSS = target area (cm^2), transformed to the standard reference range

The targets were assumed to be in the shapes of rectangles. This simplifying assumption introduces some error into the analyses reported in Section 5, although we believe it does not invalidate the results reported there. The exact size and shape of the portion of the target seen by the firing vehicle is apparently not known in all cases (it was noted that the data records contained comments that some target presentations were "partial," for example). Thus, there is some degree of "noise" in the target size information in the data base itself. Specifically, in our analyses the target sizes were assumed to be as follows:

TFR: 335x221 cm;

TFL: 610x221 cm;

BFR: 310x221 cm; and

BFL: 665x221 cm.

The miss distances X and Y are assumed to be measured horizontally and vertically from the centriod of the rectangular panels.

3. Engagement Range Analysis

Effects on engagement ranges of factors such as firing weapon system, light level, phase, and target movement were investigated. Analyses of variance (AOV) were used to test

hypotheses of no difference in mean range due to variations in nine factors (and three 2-way interactions). The AOV summary table is shown in the Appendix in Table 1. (All tables and figures are given in the Appendix.) In addition, summary statistics such as sample means and standard deviations are shown in Table 2, and histograms showing the distributions of engagement ranges for selected combinations of test conditions are shown in Figure 5. In general, these range analyses are not effected by the sample censoring problems discussed in Section 1; only the histograms of range plotted by assessment status involve potential censoring effects.

From these results one may conclude the following:

* mean engagement range (RNG) was significantly longer in phase 5 than in phase 2;
* mean RNG was significantly longer in day than at night;
* mean RNG was significantly longer for stationary firers (VEHMOT = S) than for moving firers (VEHMOT = M);
* mean RNG was significantly longer for larger targets (BFL and tanks) than for smaller targets (BFR);
* there is a significant VEH × TGTMOT interaction; and
* there is a weakly significant VEH × TGT interaction.

The nature of the two significant interactions is illustrated in Figure 5. Histograms for RNG, listed for four VEH × TGTMOT combinations and by ASMT status, are shown in Figures 6 and 7.

Analysis of Gunnery Data

4. Analyses of XS, YS and RS (conditional, given hit)

Analyses of covariance (AOC) were used to test hypotheses that the means of the standardized miss distances XS, YS, and RS are the same for differing levels of the factors PHASE, VEH, DN, VEHMOT, and TGTMOT, and the covariable TSS. TSS was included to give an impression of the possible importance of the censoring associated with target misses. It was anticipated that TSS would be significant, since it varies as a function of TGT and RNG; hits on a smaller target or at a longer range would necessarily be associated with smaller miss distances at the reference range (for otherwise, the target would have been missed, and that engagement would not be in the conditional data set). Note also that TSS is a continuous proxy for TGT, transformed to the reference range. Thus TGT is not included as a factor in these AOC's. We also did not include CDR and GNR in these AOC's, since there was a high degree of imbalance in the test design matrix with respect to these factors (in fact, there was not much repetition of levels of these factors in the two phases of the test). Preliminary analyses indicated these factors are not highly significant. However, if this issue is of interest, the AOC could be re-run with CDR and GNR included possibly as nested factors.

The AOC summary tables for the dependent variables XS and YS are shown in Table 3. The AOC summaries for RS and log-transformed RS (LOGRS, which should tend to be more nearly

normally distributed) are shown in Table 4. It can be seen that for LOGRS, only VEHMOT and TSS are significant. For the individual XS and YS measures of miss distance, the factors PHASE, DN, and TGTMOT are significant. In addition, for XS (but not YS), the VEH × TSS interaction is significant. For YS (but not XS), the covariable TSS is significant. Means for the miss-distance measures, by combinations of the significant factors, are shown in Tables 5 and 6.

5. Estimation of Means and Standard Deviations Using All Engagement Data

The degrees of censoring are different for hits at short and at long ranges, as discussed in Section 1. Since the degree of censoring is range dependent, differences in the distribution of engagement ranges over various sets of test conditions could appear to give differences in the means and variances of miss-distance measures. This is true for both conditional (given hit) estimates and unconditional (all engagement data) estimates. Figures 6 and 7 (and Tables 1 and 2) show there are differences in the range distributions over varying test conditions. The effects of tendencies toward short-range shots and toward long-range shots are summarized in the following table.

Effects on variance estimates of range dependent censoring

data considered	short shots	long shots
hit (conditional)	Inflate	Deflate
all (censored)	Inflate	Deflate

The means and standard deviations of the non-censored distributions of horizontal and vertical components of miss at the reference range were estimated by maximum likelihood estimation (MLE). We illustrate the procedure first in a one-dimensional context, then state the two-dimensional approach actually used here. Assume engagement data under given conditions (such as VEH type and TGTMOT status) and in one direction (such as horizontal), say x_1, x_2, ..., x_n, are normally distributed. Then the likelihood function L is given by

$$L = \prod_{i=1}^{n} \phi(x_i;\mu,\sigma^2)^{a_i} \times [\Phi(l_i;\mu,\sigma^2) + (1-\Phi(u_i;\mu,\sigma^2))]^{1-a_i}$$

where

ϕ and Φ are the normal(μ,σ^2) density and cumulative distribution functions, respectively;

μ and σ^2 are the population mean and variance, respectively;

x_i is the miss-distance transformed to the reference range;

l_i and u_i are the left and right censoring points (edges of

the target), transformed to the reference range; and

$a_i = 0$ if the round missed the target; $a_i = 1$ if a hit.

Note that when the round missed the target the value of x_i is not known; in that case, however, $a_i = 0$, so the first term on the right involving $\phi(x_i)$ need not be computed.

In the one dimensional case, the goal would be to find the parameter values μ and σ that maximize L, for the observed data values (i.e., the x_i's, a_i's, l_i's and u_i's). This is a non-linear optimization problem which can be solved using programs such as the GAMS software, or with a search procedure such as simulated annealing or grid search.

Now consider the likelihood function for the two-dimensional impact distribution at the reference range. The likelihood function is given by

$$L = \prod_{i=1}^{n} \phi(x_i;\mu_x,\sigma_x)^{a_i} \times \phi(y_i;\mu_y,\sigma_y)^{a_i} \times [1-(\Phi(u_x;\mu_x,\sigma_x)\Phi(u_y;\mu_y,\sigma_y) \\ -\Phi(l_x;\mu_x,\sigma_x)\Phi(u_y;\mu_y,\sigma_y) - \Phi(u_x;\mu_x,\sigma_x)\Phi(l_y;\mu_y,\sigma_y) \\ +\Phi(l_x;\mu_x,\sigma_x)\Phi(l_y;\mu_y,\sigma_y))]^{1-a_i}$$

where

ϕ, Φ, and a_i are as before;

l_x, u_x are the left- and right-edges of the target on the i^{th} shot, transformed to the reference range;

l_y and u_y are the bottom and top edges of the target on the i^{th} shot, transformed to the reference range;

μ_x and σ_x (μ_y and σ_y) are the mean and standard deviation in the horizontal (vertical) directions, respectively, at the

reference range.

This formulation assumes the horizontal and vertical components of miss are independent, and that the geometric transformation of all shots to the reference range yields miss distances that are identically distributed.

We used a numerical search routine to find successively closer approximations of the MLE's for the four parameters in the vector (μ_x, σ_x, μ_y, σ_y), using the bivariate likelihood function above. This approach seemed to be efficient in the present application, since we need solutions accurate only to the nearest integer centimeter, and it was expected the joint likelihood function would possess a single relative maximum. It appeared that the search routine worked well, and we believe the MLE's we report are accurate to within ±.2cm. Note: here we mean accurate in terms of approximating the values that precisely maximize the likelihood function; the statistical accuracy of this estimation procedure is not known, but it probably loosely follows that of the sample mean and sample standard deviation estimators for non-censored samples. The statistical accuracy could be investigated by bootstrapping methods or by simulation experiments if needed.

The results of the maximum likelihood estimation procedure are summarized in Table 7. As a general conclusion, we found no significant differences between the two firing vehicles, in terms of the estimated means and standard deviations of miss distance in either the horizontal or vertical directions. We found a

small bias in the horizontal direction (about 15cm to the left), and a more significant vertical bias (about 40cm high). The standard deviation in the horizontal direction averaged about 100cm, whereas for the vertical direction it averaged about 87cm.

The maximum likelihood estimates differ from the conditional estimates and raw hit data estimates shown in Table 7, because the latter estimates do not use information from all shots. In particular, note the standard deviation estimates obtained with the maximum likelihood method are larger than those obtained with the conditional or raw hit data. This is to be expected, since misses are taken into account by the maximum likelihood method whereas they are not with the other two methods. Note misses would tend to have more extreme X or Y components, hence omitting misses gives estimates of standard deviations that are biased low.

6. Comparisons of Fractions of Misses with Estimated P[Miss]

The estimated means and standard deviations, together with standard calculations with the normal distribution can be used to estimate the probabilities of miss that should be observed under varying test conditions. These can then be compared with the observed fractions of misses under the same conditions, as a consistency check. In what follows we consider an example in which the condition is range. This comparison is only approximate because it does not take into account the

distribution of engagement ranges under the given conditions, nor does it account for varying target sizes. (The computations could be done shot-by-shot, with range and specific target appropriately accounted for, if there is sufficient interest in this issue.)

Suppose the overall averages of the estimated means and standard deviations are applied to normal distributions with truncation points corresponding to the overall average target size, all at the reference range. We estimate the probability of miss of the average target using our estimates and compare it with the observed miss proportion, as follows (all figures approximate):

estimated $\mu_x = -15$

estimated $\mu_y = 40$

estimated $\sigma_x = 100$

estimated $\sigma_y = 87$

average target width = 480

average target height = 221.

Let p_x denote the probability of hitting within the width of the target at the reference range and similarly for p_y and the target height. Then

$$p_x = P[-240 \le XS \le 240] \approx P[-2.5 \le Z \le 2.25] = .983$$

and

$$p_y = P[-111 \le YS \le 111] \approx P[-1.74 \le Z \le 0.82] = .753$$

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where Z is a standard normal random variable. Thus, assuming independence in the horizontal and vertical components of miss (which seems reasonable in view of plots of hit pairs even though there is significant positive correlation between XS and YS [ρ=.195; p<.003]), P[miss] = $1-p_x p_y \approx 0.26$.

This value is somewhat below the observed fraction of misses overall (approximately .32). There are several possible explanations for this difference. There may be too much averaging here; possibly analyses under given conditions (VEH, TGTMOT, TGT, etc.) would give estimates of miss probabilities nearer the fractions observed under corresponding conditions, but we have not carried out such computations. It is possible that the varying ranges at engagement and accompanying effects on apparent target sizes at the reference range must be taken into account shot by shot, rather than averaged. It is possible that the actual targets presented to the firing vehicle were partially hidden in a non-negligible fraction of the engagements, so some targets were in reality smaller than the dimensions we assumed; a related "over statement of size" results from our assumption that targets are rectangular in shape. (Note that over-statement of target size should lead to variance estimates that are biased high, which should in turn make the estimates of probability of miss biased high.)

Finally, if some proportion of misses were due to gross errors by the firing vehicle crew, the estimation procedure we

have used assuming a single miss distribution for all shots (at the reference range) would tend to provide estimates of the standard deviations that are biased <u>low</u>, which would make the estimated miss probabilities too low.

There are a couple of errors that could be made by the gunners which could cause a significant fraction of misses to represent a different distribution than the rounds which hit. The correct elevation angle for example is a function of ammunition type and the actual range to the target. If the ammo type fired does not match the type expected by the fire control computer a gross elevation error would result. Also, if the gunner were to miss the target with the laser range finder above or to the side, the range used in the FCC solution would tend to be much greater than the actual range, also resulting in a gross elevation error. For moving targets, these same two error types would result in a significant "lead" or azimuth error. The distribution of these errors could be thought of as a step function, while that for most other errors could be characterized as continuous. The resultant distributions could then be broken down into those cases where the crew did all activities correctly, and those engagements where some significant error occurred. The distribution estimated by those rounds which hit the target would represent the performance given no gross errors and yield an expected miss probability under "normal" performance. The difference between this estimated miss

probability and the demonstrated miss probability could then be attributed to the frequency of occurrence of "non-normal performance" or gross errors by the crew.

We attempted to gain some idea of the relative frequency of such gross errors by investigating systematic differences between observed and predicted miss frequencies. This was done by including geometric effects of range upon the estimated miss probabilities, and comparing these with the corresponding fractions of misses observed within selected range bands. Figure 11 shows the overall fraction of misses, as a function of range bands centered 150m apart. Also shown in the figure are lower- and upper-90% confidence limits on the theroetical proportion of misses, plotted as a function of range. It can be seen in the figure that over most of the range the fraction of misses is roughly increasing, except for a very low incidence of misses at 1650m. Estimated P[miss], calculated with the apparent average target size and parameter vector (means and standard deviations) at the various ranges, has a theoretically increasing trend with range. For example, at a range of 1500m, $p_x \approx .9498$ and $p_y \approx .6598$, so P[miss] $\approx$ .373.

Over most of the range, the calculated P[miss] values fall somewhat below the observed fraction of misses for that range. For example, at 750m, the calculated P[miss] is .055 whereas for the range band centered at 750m the observed fraction of misses was .11. Such considerations suggest that on average, the tank

crews missed more targets than theoretically would have been expected at short- and mid-ranges. We therefore hypothesize there might be a fraction of at least .05 of misses due to gross errors. If this is true, the actual probability of miss would be the calculated value plus .05.

We have plotted P[miss]+0.05 as a function of range in Figure 11, to facilitate comparisons with the observed fractions of misses. As can be seen, there is fair agreement between the two curves, except at the longest range band at 1650m. (Note, for example, the curve corresponding to P[miss]+0.05 falls within the 90% confidence band related to fractions of misses, except at the longest range.)

At the range band corresponding to 1650m, as mentioned above, the observed fraction of misses falls significantly below the estimated probability. Perhaps there is a physical explanation in terms of the targets that were presented at the longest ranges, or the times the crews took in firing on targets at these ranges, or in the order in which targets were presented to the crews. The apparent abrupt improvement in gunnery at the longest ranges seems to be an interesting issue; additional analyses might reveal important information concerning these gunnery factors.

Acknowledgement

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7. References

Glumm, M., West, W.D., and Lee, R., 1982, "Evaluation of Gunner Station Configurations for Firing-On-The-Move: Phase II, US Army Human Engineering Laboratory, APG Maryland".

Johnson, N., and S. Kotz, 1970, "Distributions in Statistics: Continuous Univariate Distributions," Vol. 1, Houghton Mifflin Co., pp. 81-87.

Kendall, M., and A. Stuart, 1979, "The Advanced Theory of Statistics," Vol. 4, Fourth edition, pp. 551-555.

S. Kotz and N. Johnson (Editors), 1982, "Encyclopedia of Statistical Sciences," Vol. 1, John Wiley & Sons, pp. 389-396.

West, W. D., and Anstice, D., 1982, "Vol II, Conduct of Special Study High Survivability Test Vehicle-Light (HSTV-L), US Army Armor and Engineer Board, Ft Knox, Ky.

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DATA SUMMARIES BY SELECTED FACTORS

```
ASE                                                                 CUM                   CUM
                                                           FREQ     FREQ     PERCENT     PERCENT

[************************************                      166      166       45.73       45.73

[*******************************************               197      363       54.27      100.00

0--20--40--60--80--100--120--140--160--180--
            Frequency

ENT

 [***************************                               64       64       17.63       17.63

 [*************                                             33       97        9.09       26.72

 [*********                                                 25      122        6.89       33.61

 [***************************                               61      183       16.80       50.41

 [*************************                                 55      238       15.15       65.56

 [***********************                                   52      290       14.33       79.89

 [***********************                                   52      342       14.33       94.21

 [*********                                                 21      363        5.79      100.00

 0---10---20---30---40---50---60---
       Frequency

H

[********************************                          166      166       45.73       45.73

[*****************************************                 197      363       54.27      100.00

0--20--40--60--80--100--120--140--160--180--
              Frequency


[****************************************                  198      198       54.55       54.55

[********************************                          165      363       45.45      100.00

0-20--40--60--80--100--120--140--160--180--200--
             Frequency
```

FIG 1.

DATA SUMMARIES BY SELECTED FACTORS
(cont')

ASMT

	FREQ	CUM FREQ	PERCENT	CUM PERCENT
[**************************************	241	241	66.39	66.39
[*****************	122	363	33.61	100.00

0--30--60--90--120--150--180--210--240--
Frequency

EHMOT

	FREQ	CUM FREQ	PERCENT	CUM PERCENT
[**********************	142	142	40.23	40.23
[********************************	211	353	59.77	100.00

0--30--60--90--120--150--180--210--
Frequency

GTMOT

	FREQ	CUM FREQ	PERCENT	CUM PERCENT
[****************	104	104	29.46	29.46
[***************************************	249	353	70.54	100.00

0--30--60--90--120--150--180--210--240--
Frequency

DR

		FREQ	CUM FREQ	PERCENT	CUM PERCENT
	[*****************************	37	37	10.19	10.19
	[**************************	33	70	9.09	19.28
	[*********************************	40	110	11.02	30.30
	[******************************	38	148	10.47	40.77
9	[************************************	41	189	11.29	52.07
9	[*****************************	37	226	10.19	62.26
3	[*************************	33	259	9.09	71.35
6	[************	18	277	4.96	76.31
0	[*****************************	38	315	10.47	86.78
3	[***************************	34	349	9.37	96.14
2	[*********	14	363	3.86	100.00

0-5--10--15--20--25--30--35--40--
Frequency

FIG 2.

DATA SUMMARIES BY SELECTED FACTORS
(cont')

GT

		FREQ	CUM FREQ	PERCENT	CUM PERCENT
FL	[***	20	20	5.51	5.51
FR	[********************	100	120	27.55	33.06
FL	[******************	97	217	26.72	59.78
FR	[*********************************	146	363	40.22	100.00

0--20--40--60--80--100--120--140--
Frequency

NG
idpoint

		FREQ	CUM FREQ	PERCENT	CUM PERCENT
50		1	1	0.29	0.29
00		1	2	0.29	0.58
50	[*	7	9	2.02	2.59
00	[****	28	37	8.07	10.66
050	[*************	76	113	21.90	32.56
200	[*********	43	156	12.39	44.96
350	[*****************************	137	293	39.48	84.44
500	[*********	41	334	11.82	96.25
650	[**	11	345	3.17	99.42
800		2	347	0.58	100.00

0--20--40--60--80--100--120--
Frequency

NR

		FREQ	CUM FREQ	PERCENT	CUM PERCENT
	[*********	14	14	3.86	3.86
	[******************************	40	54	11.02	14.88
0	[**********	17	71	4.68	19.56
3	[**********	17	88	4.68	24.24
6	[***********************	33	121	9.09	33.33
0	[****************************	38	159	10.47	43.80
1	[**************************	35	194	9.64	53.44
6	[**************	20	214	5.51	58.95
7	[***************************	37	251	10.19	69.15
1	[****************************	38	289	10.47	79.61
2	[***********************	33	322	9.09	88.71
7	[*********************************	41	363	11.29	100.00

0--5--10--15--20--25--30--35--40--
Frequency

FIG 3.

DATA SUMMARIES BY SELECTED FACTORS

idpoint	FREQ	CUM FREQ	PERCENT	CUM PERCENT
100 [*	2	2	0.83	0.83
75 [****	14	16	5.81	6.64
50 [********	21	37	8.71	15.35
25 [************	32	69	13.28	28.63
0 [*****************	46	115	19.09	47.72
25 [**********************	55	170	22.82	70.54
50 [***************	39	209	16.18	86.72
75 [********	22	231	9.13	95.85
100 [***	10	241	4.15	100.00

0--10--20--30--40--50--
Frequency

idpoint	FREQ	CUM FREQ	PERCENT	CUM PERCENT
270 [**	5	5	2.07	2.07
210 [*	1	6	0.41	2.49
150 [****	11	17	4.56	7.05
90 [****************	41	58	17.01	24.07
30 [*****************************	76	134	31.54	55.60
30 [**************************	67	201	27.80	83.40
90 [************	33	234	13.69	97.10
150 [**	5	239	2.07	99.17
210 [*	1	240	0.41	99.59
270 [*	1	241	0.41	100.00

0--10--20--30--40--50--60--70--
Frequency

FIG 4.

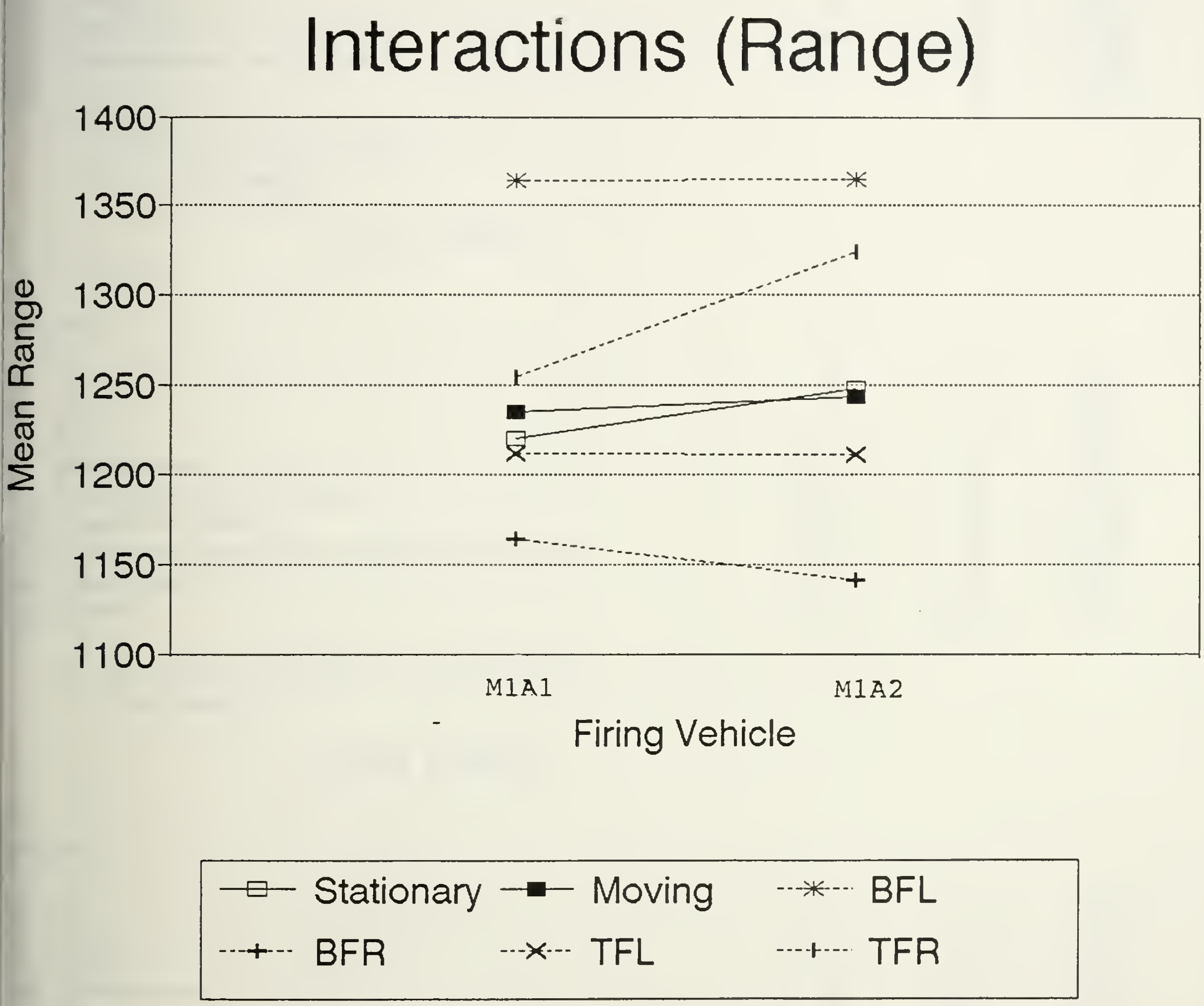

Interactions (Range)
1400
1350
1300
1250
1200
1150
1100
Mean Range
M1A1
M1A2
Firing Vehicle
Stationary
Moving
BFL
BFR
TFL
TFR

FIG 5.

HISTOGRAMS OF RNG BY VEH X TGT MEANS

```
                    VEH=1 TGTMOT=M
G                                                                   CUM                 CUM
dpoint                                                     FREQ     FREQ    PERCENT    PERCENT

0   [**                                                      2         2      4.65       4.65
0   [***                                                     3         5      6.98      11.63
20  [****                                                    4         9      9.30      20.93
40  [******                                                  6        15     13.95      34.88
60  [*****                                                   5        20     11.63      46.51
80  [**********************                                 22        42     51.16      97.67
00  [*                                                       1        43      2.33     100.00

     0----5----10----15---20----
              Frequency

                    VEH=1 TGTMOT=S

G
dpoint

0   [*                                                       1         1      0.91       0.91
0   [*                                                       1         2      0.91       1.82
0   [**                                                      2         4      1.82       3.64
0   [*********                                              11        15     10.00      13.64
50  [**********************                                 25        40     22.73      36.36
00  [**************                                         16        56     14.55      50.91
50  [***********************************                    37        93     33.64      84.55
00  [***********                                            13       104     11.82      96.36
50  [****                                                    4       110      3.64     100.00

     0---5---10---15---20---25---30---35---
         Frequency

                    VEH=2 TGTMOT=M

G
dpoint

0   [*                                                       1         1      1.79       1.79
0   [*                                                       1         2      1.79       3.57
0   [****                                                    5         7      8.93      12.50
80  [*********                                               9        16     16.07      28.57
00  [****                                                    4        20      7.14      35.71
20  [****************************                           25        45     44.64      80.36
40  [***********                                            11        56     19.64     100.00

     0----5----10----15----20----25--
                Frequency
```

FIG 6.

VEH=2 TGTMOT=S

NG
lidpoint

		CUM FREQ	FREQ	CUM PERCENT	PERCENT
'80	[**	3	3	2.33	2.33
00	[****	7	10	5.43	7.75
.020	[************	28	38	21.71	29.46
.140	[******	16	54	12.40	41.86
.260	[*****	11	65	8.53	50.39
.380	[**********************	46	111	35.66	86.05
.500	[***	10	121	7.75	93.80
.620	[**	7	128	5.43	99.22
.740	[*	1	129	0.78	100.00

0---10---20---30---40---
Frequency

FIG 6 (CONT.)

HISTOGRAMS OF RNG OVERALL AND BY ASST

```
NG                                                              CUM                  CUM
idpoint                                         FREQ    FREQ   PERCENT  PERCENT

50  [                                                      1         1      0.29       0.29
00  [                                                      1         2      0.29       0.58
50  [*                                                     7         9      2.02       2.59
00  [******                                               28        37      8.07      10.66
050 [*******************                                  76       113     21.90      32.56
200 [************                                         43       156     12.39      44.96
350 [*************************************               137       293     39.48      84.44
500 [***********                                          41       334     11.82      96.25
550 [**                                                   11       345      3.17      99.42
300 [                                                      2       347      0.58     100.00
    0----20---40----60---80---100---120---
             Frequency

                      ASMT=H

NG
idpoint

50  [                                                      1         1      0.42       0.42
00  [                                                      0         1      0.00       0.42
50  [**                                                    7         8      2.97       3.39
00  [*******                                              21        29      8.90      12.29
050 [*******************                                  51        80     21.61      33.09
200 [**********                                           29       109     12.29      46.19
350 [***************************************              96       205     40.68      86.86
500 [***********                                          19       224      8.05      94.92
550 [****                                                 11       235      4.66      99.58
300 [                                                      1       236      0.42     100.00
    0--10--20--30--40--50--60--70--80--90---
        Frequency

                      ASMT=M
IG
dpoint

00  [*                                                     1         1      0.90       0.90
50  [                                                      0         1      0.00       0.90
00  [****                                                  7         8      6.31       7.21
050 [******************                                   25        33     22.52      29.73
200 [*********                                            14        47     12.61      42.34
50  [********************************                     41        88     36.94      79.20
00  [***************                                      22       110     19.82      99.10
50  [                                                      0       110      0.00      99.10
00  [*                                                     1       111      0.90     100.00
    0--5--10--15--20--25--30--35--40----
              Frequency
```

FIG 7.

HISTOGRAMS OF XS BY VEH X TGTMOT

```
              VEH =1 TGTMOT=S
G                                                            CUM                CUM
dpoint                                              FREQ     FREQ    PERCENT    PERCENT

20  [************                                      9        9      11.54      11.54
0   [************                                      9       18      11.54      23.08
0   [***********************                          14       32       9.30      20.93
0   [***************                                  10       42      12.82      53.85
0   [*********************                            13       55      16.67      70.51
0   [*******************                              12       67      15.38      85.90
0   [******                                            4       71       2.56      93.59
0   [***                                               2       73       2.56      93.59
0   [*******                                           5       78       6.41     100.00
    0--2--4--6--8--10--12--14-----
            Frequency

              VEH=2 TGTMOT=S

G
dpoint

20 [************                                       9        9      10.47      10.47
0  [*********                                          7       16       8.14      18.60
0  [****************************                      16       32      18.60      37.21
0  [*******************                               12       44      13.95      51.16
0  [*********************                             13       57      15.12      66.28
0  [*********************                             13       70      15.12      81.40
0  [************                                       8       78       9.30      90.70
0  [***                                                2       80       2.33      93.02
0  [*********                                          6       86       6.98     100.00

   0--2--4--6--8--10--12--14--16---
            Frequency

              VEH=1 TGTMOT=M

G
dpoint

20 [*******************                                6        6      19.35      19.35
0  [********                                           3        9       9.68      29.03
0  [*****                                              2       11       6.45      35.48
0  [***************                                    5       16      16.13      51.61
   [*************                                      4       20      12.90      64.52
0  [***************                                    5       25      16.13      80.65
0  [*************                                      4       29      12.90      93.55
0  [***                                                1       30       3.23      96.77
0  [***                                                1       31       3.23     100.00

   0--1--2--3--4--5--6--
            Frequency
```

FIG 8.

```
                     VEH=2   TGTMOT=M

S
idpoint                                                                    CUM                    CUM
                                                            FREQ           FREQ      PERCENT      PERCENT

120   [************************                             6              6       16.67        16.67
90    [************************                             6             12       16.67        33.33
60    [****************************                         7             19       19.44        52.78
30    [****************                                     4             23       11.11        63.89
0     [*******                                              2             25        5.56        69.44
30    [********************                                 5             30       13.89        83.33
60    [****                                                 1             31        2.78        86.11
90    [************                                         3             34        8.33        94.44
20    [********                                             2             36        5.56       100.00
      0---1---2---3---4---5---6---7
                Frequency
```

FIG 8 (CONT)

HISTOGRAMS OF YS BY VEH x TGTMOT

```
                         VEH=1 TGMOT=S
                                                                 CUM                 CUM
dpoint                                                  FREQ     FREQ     PERCENT    PERCENT

20   [*                                                    1        1       1.28       1.28
0    [***                                                  3        4       3.85       5.13
0    [****                                                 4        8       5.13      10.26
0    [*************                                       13       21      16.67      26.92
     [************************                            23       44      29.49      56.41
0    [********************                                19       63      24.36      80.77
0    [**********                                           9       72      11.54      92.31
0    [****                                                 4       76       5.13      97.44
0    [**                                                   2       78       2.56     100.00
     0-----5----10---15---20---
             Frequency

                       VEH=1 TGTMOT=M


dpoint

20  [                                                      0        0       0.00       0.00
0   [*******                                               3        3       9.68       9.68
0   [**************                                        5        8      16.13      25.81
0   [*******                                               3       11       9.68      35.48
    [**************************                           11       22      35.48      70.97
0   [********************                                  8       30      25.81      96.77
0   [                                                      0       30       0.00      96.77
0   [**                                                    1       31       3.23     100.00
0   [                                                      0       31       0.00     100.00
    0---2---3---4---6---8---10----
             Frequency

                       VEH=2 TGTMOT=S

dpoint

20  [*                                                     1        1       1.16       1.16
)   [******                                                5        6       5.81       6.98
)   [*********************                                13       19      15.12      22.09
)   [****************************                         17       36      19.77      41.86
    [*************************************                21       57      24.42      66.28
)   [***********************                              14       71      16.28      82.56
)   [***********                                           7       78       8.14      90.70
)   [*********                                             6       84       6.98      97.67
)   [***                                                   2       86       2.33     100.00
    0--2--4--6--8--10--12--14--16--18--20---
             Frequency
```

FIG 9.

```
                        VEH=2 TGMOT=M
S                                                                 CUM                 CUM
idpoint                                                   FREQ    FREQ    PERCENT   PERCENT

120  [                                                       0       0       0.00      0.00
90   [***                                                    1       1       2.78      2.78
60   [***********************************                    9      10      25.00     27.78
30   [***********************                                6      16      16.67     44.44
 0   [***********************                                6      22      16.67     61.11
30   [*******************************                        8      30      22.22     83.33
60   [*******************                                    5      35      13.89     97.22
90   [***                                                    1      36       2.78    100.00
20   [                                                       0      36       0.00    100.00
     0---1---2---3---4---5---6---7---8---9----
             Frequency
```

FIG 9 (CONT)

HISTOGRAMS OF XS AND YS overall

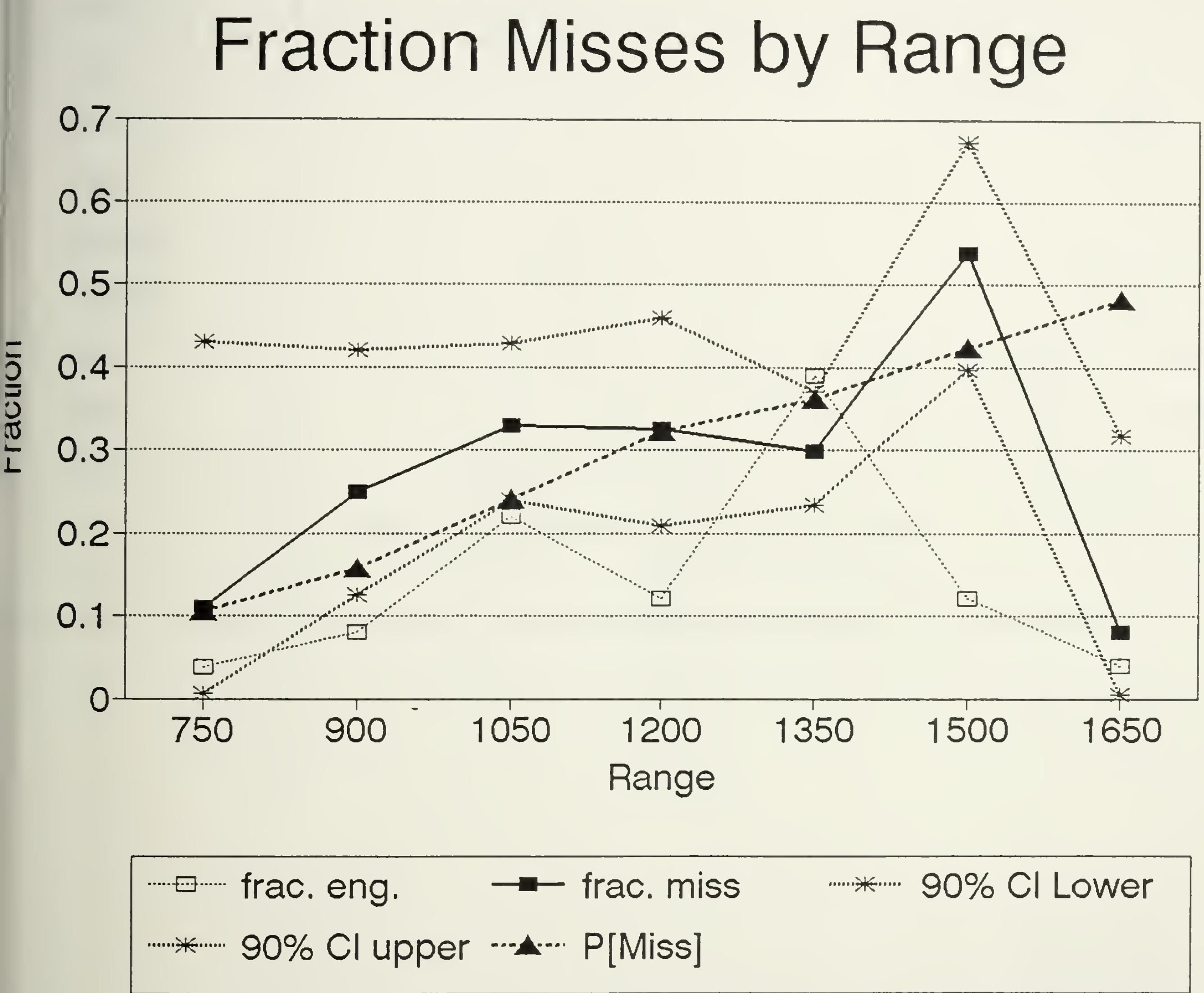
```
                                                                    CUM                 CUM
dpoint                                                     FREQ     FREQ    PERCENT    PERCENT

240   [**                                                    8        8       3.39       3.39
160   [****                                                 12       20       5.08       8.47
30    [***********************                              59       79      25.00      33.47
 0    [**************************************               97      176      41.10      74.58
30    [*******************                                  49      225      20.76      95.34
50    [***                                                  10      235       4.24      99.58
40    [                                                      0      235       0.00      99.58
20    [                                                      0      235       0.00      99.58
00    [                                                      1      236       0.42     100.00
      0--10--20--30--40--50--60--70--80--90---
               Frequency


dpoint

05  [*                                                       2        2       0.85       0.85
5   [****                                                   13       15       5.51       6.36
5   [**************                                         31       46      13.14      19.49
5   [******************                                     39       85      16.53      36.02
5   [********************************                       62      147      26.27      62.29
5   [*************************                              50      197      21.19      83.47
5   [**********                                             21      218       8.90      92.37
5   [******                                                 14      232       5.93      98.31
5   [*                                                       2      234       0.85      99.15
5   [*                                                       1      235       0.42      99.58
5   [*                                                       1      236       0.42     100.00
    0---10---20---30---40---50---60----
              Frequency
```

FIG 10.



Fraction Misses by Range
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
750
900
1050
1200
1350
1500
1650
Range
frac. eng.
frac. miss
90% CI Lower
90% CI upper
P[Miss]

FIG 11.

AOV SUMMARY FOR RNG

Class Level Information

Class	Levels	Values											
Phase	2	2	5										
VEH	2	1	2										
DN	2	D	N										
ASMT	2	H	M										
VEHMOT	2	M	S										
TGTMOT	2	M	S										
CDR	11	1	3	4	9	19	29	33	36	40	43	52	
GNR	12	6	8	10	13	16	20	21	26	27	31	32	47
TGT	4	BFL	BFR	TFL	TFR								

Number of observations in data set = 363

ite: Due to missing values, only 334 observations can be used in this analysis.

TBL 1

	Mean Square	F Value	PR > F
846	301760.0105	13.62	0.0001
837	22162.1620		
683			

Root MSE	RNG Mean
148.86961	1236.7545

	Mean Square	F Value	PR > F
2	138795.0402	6.26	0.0129
6	28958.1226	1.31	0.2539
7	104600.6647	4.72	0.0306
9	25673.9649	1.16	0.2826
	5228592.5805	235.92	0.0001
3	35380.1523	1.60	0.2074
4	6610.6664	0.30	0.5854
2	21734.9601	0.98	0.3762
4	162440.0758	7.33	0.0001
6	27592.5976	1.25	0.2654
4	7485.0004	4.32	0.5616
3	140127.7563	6.32	0.0124
4	57807.7758	2.61	0.0517

SD
226.868064
196.561248

SD
205.714601
213.848563

SD
147.837725
162.258759

SD
38.709822
171.449970
196.263901
234.983357

SD
182.939600
230.359965
179.946550
218.028597

SD
37.269663
178.831815
191.807620
256.791524
41.977375
165.380150
201.259418
211.242591

TBL 1 (CONT.)

TABLES OF RNG MEANS

el of SE	N	RNG MEAN	RNG SD
	143	1203.31469	226.868064
	191	1261.79058	196.561248

el of	N	RNG MEAN	RNG SD
	180	1267.00556	205.714601
	154	1201.39610	213.848563

el of MOT	N	RNG MEAN	RNG SD
	136	1064.69118	147.837725
	198	1354.93939	162.258759

el of	N	RNG MEAN	RNG SD
	19	1364.68421	38.709822
	93	1152.40860	171.449970
	85	1210.87059	196.263901
	137	1292.32847	234.983357

el of	Level of TGTMOT	N	RNG MEAN	RNG SD
	M	42	1234.92857	182.939600
	S	110	1220.41818	230.359965
	M	56	1243.44643	179.946550
	S	126	1248.65079	218.028597

el of	Level of TGT	N	RNG MEAN	RNG SD
	BFL	9	1364.44444	37.269663
	BFR	45	1164.00000	178.831815
	TFL	35	1211.31429	191.807620
	TFR	63	1254.87302	256.791524
	BFL	10	1364.90000	41.977375
	BFR	48	1141.54167	165.380150
	TFL	50	1210.56000	201.259418
	TFR	74	1324.21622	211.242591

TBL 2.

AOV SUMMARIES FOR XS AND YS

ependent Variable: XS

ource	DF	Sum of Squares	Mean Square	F Value	Pr > F
odel	9	227392.31231	25265.81248	3.68	0.0003
rror	219	1505477.55475	6874.32673		
orrected TL	228	1732869.86706			

R-Square	C.V.	Root MSE	XS Mean
0.131223	-750.3442	82.911560	-11.049804

ource	DF	Type IV SS	Mean Square	F Value	Pr > F
HASE	1	115979.86337	115979.86337	16.87	0.0001
EH	1	22731.18066	22731.18066	3.31	0.0704
N	1	26526.81183	26526.81183	3.86	0.0507
EHMOT	1	120.13511	120.13511	0.02	0.8950
GTMOT	1	37710.89878	37710.98978	5.49	0.0201
SS	1	9788.40079	9788.40079	1.42	0.2341
EH*TGTMOT	1	2441.40287	2441.40287	0.36	0.5518
EH*VEHMOT	1	8973.19149	8973.19149	1.31	0.2545
SS*VEH	1	31497.78527	31497.78527	4.58	0.0334

ependent Variable: YS

ource	DF	Sum of Squares	Mean Square	F Value	Pr > F
odel	9	101977.53518	11330.83724	5.62	0.0001
rror	219	441173.31305	2014.49001		
orrected Total	228	543150.84822			

R-Square	C.V.	Root MSE	XS Mean
0.187752	307.1100	44.883070	14.614654

ource	DF	Type IV SS	Mean Square	F Value	Pr > F
HASE	1	8198.242548	8198.242548	4.07	0.0449
EH	1	1036.557372	1036.557372	0.51	0.4739
N	1	10089.995730	10089.995730	5.01	0.0262
EHMOT	1	9726.728231	9726.728231	4.83	0.0290
GTMOT	1	26509.855430	26509.855430	13.16	0.0004
SS	1	60440.503615	60440.503615	30.00	0.0001
EH*TGTMOT	1	222.525627	222.525627	0.11	0.7399
EH*VEHMOT	1	8.098059	8.098059	0.00	0.9495
SS*VEH	1	1216.528438	1216.528438	0.60	0.4379

TBL 3 (CONT.)

AOV SUMMARIES FOR RS AND LOGRS

ependent Variable: RS

ource	DF	Sum of Squares	Mean Square	F Value	Pr > F
odel	9	184557.26838	20506.36315	7.73	0.0001
rror	219	580997.65195	2652.95731		
orrected Total	228	765554.92032			

R-Square	C.V.	Root MSE	XS Mean
0.241076	61.86545	51.506867	83.256272

ource	DF	Type IV SS	Mean Square	F Value	Pr > F
HASE	1	6791.400296	6791.400296	2.56	0.1110
EH	1	3122.261036	3122.261036	1.18	0.2792
N	1	75.888562	75.888562	0.03	0.8658
EHMOT	1	19039.957627	19039.957627	7.18	0.0079
GTMOT	1	33.611026	33.611026	0.01	0.9105
SS	1	53496.976974	53496.976974	20.17	0.0001
EH*TGTMOT	1	697.360560	697.360560	0.26	0.6087
EH*VEHMOT	1	31.002146	31.002146	0.01	0.9140
SS*VEH	1	3566.899764	3566.899764	1.34	0.2475

TBL 4

ependent Variable: LOGRS

ource	DF	Sum of Squares	Mean Square	F Value	Pr > F
odel	9	17.50867153	1.94540795	4.78	0.0001
rror	218	88.80279254	0.40735226		
orrected Total	227	106.31146408			

R-Square	C.V.	Root MSE	LOGRS Mean
0.164692	15.15751	0.6382415	4.2107281

ource	DF	Type IV SS	Mean Square	F Value	Pr > F
HASE	1	0.07315857	0.07315857	0.18	0.6721
EH	1	0.34167706	0.34167706	0.84	0.3608
N	1	0.41739921	0.41739921	1.02	0.3125
EHMOT	1	2.40381253	2.40381253	5.90	0.0159
GTMOT	1	0.15933578	0.15933578	0.39	0.5323
SS	1	3.78040619	3.78040619	9.28	0.0026
EH*TGTMOT	1	0.14431878	0.14431878	0.35	0.5523
EH*VEHMOT	1	0.01250686	0.01250686	0.03	0.8611
SS*VEH	1	0.14904826	0.14904826	0.37	0.5459

TBL 4 (CONT.)

MEANS FOR XS,YS, R, RS, AND TSS

evel of HASE	N	XS MEAN	XS SD	YS MEAN	YS SD
	94	16.5588061	74.6588749	24.9640852	48.2923690
	135	-30.2735773	90.3125956	7.4083837	48.0346287

evel of HASE	N	R MEAN	R SD	RS MEAN	RS SD
	94	73.5338825	39.6336997	79.7070205	48.9042572
	135	82.4657571	53.7385082	85.7276023	63.5471985

Level of PHASE	N	TSS MEAN	TSS SD
2	94	113.990668	80.1939952
5	135	97.789999	54.8078721

evel of N	N	XS MEAN	XS SD	YS MEAN	YS SD
	139	-6.8834282	93.8087649	8.0942212	43.9640431
	90	-17.4845405	75.8708869	24.6851007	54.1929916

evel of N	N	R MEAN	R SD	RS MEAN	RS SD
	139	79.5759366	54.6507471	81.8849991	63.9757486
	90	77.6000774	37.4913501	85.3741262	47.4128608

Level of DN	N	TSS MEAN	TSS SD
D	139	109.028134	68.4900919
N	90	97.354024	63.6324710

evel of EH	N	R MEAN	R SD	YS MEAN	YS SD
	108	-8.6319095	89.7099024	18.4721818	48.1559423
	121	-13.2079250	85.1739981	11.1715717	49.3268755

evel of EH	N	R MEAN	R SD	RS MEAN	RS SD
	108	76.2810030	49.1687469	82.4242822	62.6835119
	121	81.0472217	48.0885546	83.9988740	53.6179860

TBL 5.

VEH	Level of N	----TSS---- MEAN	SD
1	108	106.149542	74.2955479
2	121	102.914233	59.4375332

vel of H	Level of TGTMOT	N	----XS---- MEAN	SD	----YS---- MEAN	SD
	M	30	-13.7067884	125.433301	5.0718214	41.9310012
	S	78	-6.6800330	72.414755	23.6261666	49.6331133
	M	36	-29.4109607	99.007880	9.6591497	44.4261463
	S	85	-6.3454628	78.225047	11.8121270	51.4990485

vel of H	Level of TGTMOT	N	----R---- MEAN	SD	----RS---- MEAN	SD
	M	30	90.1230330	69.3375471	96.7426487	89.6148295
	S	78	70.9571453	38.0187095	76.9172182	48.2171871
	M	36	94.9805949	63.7938011	94.8909640	59.1638912
	S	85	75.1460284	38.5934743	79.3857536	50.7554795

TBL 5 (CONT.)

MEANS FOR XS, YS, R, RS, AND TSS

Level of VEH	Level of TGTMOT	N	TSS MEAN	TSS SD
1	M	30	154.095512	63.8082682
1	S	78	87.708785	69.9776407
2	M	36	149.612399	62.4510949
2	S	85	83.136186	45.7318983

Level of VEH	Level of TGT	N	XS MEAN	XS SD	YS MEAN	YS SD
	BFL	8	4.0877649	105.201435	45.1542109	23.2475865
	BFR	33	-17.7520700	81.525226	19.1452203	48.4404541
	TFL	23	-11.9722645	136.417366	-7.5574982	37.8962389
	TFR	44	-2.3583627	60.140504	26.7225485	51.3488595
	BFL	7	-16.4221428	47.117597	-1.0088772	41.5722195
	BFR	28	-7.3961125	85.712033	13.4387367	57.8830971
	TFL	33	-37.4846542	111.330123	14.4900213	50.1036266
	TFR	53	-0.7505507	67.024021	9.5163583	45.8094157

Level of VEH	Level of TGT	N	R MEAN	R SD	RS MEAN	RS SD
	BFL	8	112.243826	53.8245678	101.294546	47.230084
	BFR	33	80.439138	36.5897813	87.622814	42.167884
	TFL	23	87.216641	76.0265875	98.439776	100.620690
	TRF	44	60.907351	32.1080894	66.722691	49.340935
	BFL	7	61.438254	28.0160266	55.705234	25.374937
	BFR	28	77.499358	46.7973511	87.142333	55.371338
	TFL	33	103.626024	64.7133952	108.651138	66.293108
	TFR	53	71.452929	32.4941967	70.725552	39.815836

Level of VEH	Level of TGT	N	TSS Mean	TSS SD
1	BFL	8	120.169977	6.4218140
1	BFR	33	82.594301	27.5844505
1	TFL	23	163.889837	70.2266469
1	TFR	44	91.084377	90.3398530
2	BFL	7	121.131847	8.3905312
2	BFR	28	85.765723	26.6088813
2	TFL	33	162.593026	75.9548075
2	TFR	53	72.409229	28.5478295

TBL 6.

Level of DN	N	------TSS------------------ MEAN	SD
D	139	109.028134	68.4900919
N	90	97.354024	63.6324710

evel of EH	N	-----R--------------------- MEAN	SD	--------YS---------- MEAN	SD
	108	-8.6319095	89.7099024	18.4721818	48.1559423
	121	-13.2079250	85.1739981	11.1715717	49.3268755

evel of EH	N	------R--------------------- MEAN	SD	--------RS---------- MEAN	SD
	108	76.2810030	49.1687469	82.4242822	62.6835119
	121	81.0472217	48.0885546	83.9988740	53.6179860

Level of VEH	N	----TSS------------------- MEAN	SD
1	108	106.149542	74.2955479
2	121	102.914233	59.4375332

evel of EH	Level of TGTMOT	N	----------XS--------- MEAN	SD	--------YS---------- MEAN	SD
	M	30	-13.7067884	125.433301	5.0718214	41.9310012
	S	78	-6.6800330	72.414755	23.6261666	49.6331133
	M	36	-29.4109607	99.007880	9.6591497	44.4261463
	S	85	-6.3454628	78.225047	11.8121270	51.4990485

evel of EH	Level of TGTMOT	N	----------R----------- MEAN	SD	---------RS---------- MEAN	SD
	M	30	90.1230330	69.3375471	96.7426487	89.6148295
	S	78	70.9571453	38.0187095	76.9172182	48.2171871
	M	36	94.9805949	63.7938011	94.8909640	59.1638912
	S	85	75.1460284	38.5934743	79.3857536	50.7554795

TBL 6. (CONT)

MLE, Censored, and Raw Estimates of the Mean and Std. Dev.
by VEH x TGTMOT

Condition	means				standard dev.			
	1,M	1,S	2,M	2,S	1,M	1,S	2,M	2,S
MLE:								
horiz.	-30.5	-13.0	-15.3	-14.4	202.4	70.6	119.2	70.0
vert.	24.0	43.7	43.5	40.0	62.1	75.1	94.0	96.3
Conditional:								
XS	-13.7	-6.7	-29.4	-6.3	125.4	72.4	99.0	78.2
YS	5.1	23.6	9.7	11.8	41.9	49.6	44.4	51.5
Raw Hit Data:								
X	-17.4	-7.2	-34.2	-4.9	105.0	65.9	101.5	69.4
Y	5.8	19.5	7.4	8.9	43.0	42.0	42.4	47.7
Sample Sizes:								
	62	92	73	111				

MLE, Censored, and Raw Estimates of the Mean and Std. Dev.
by VEH

Condition	means		standard dev.	
	VEH=1	VEH=2	VEH=1	Veh=2
MLE:				
horiz.	-16.9	-14.6	110.2	96.0
vert.	39.5	41.8	79.7	93.9
Conditional:				
XS	-8.6	-13.2	89.7	85.2
YS	18.5	11.2	48.2	49.3
Raw Hit Data:				
X	-10.0	-13.6	78.3	81.0
Y	15.7	8.5	42.6	46.0
Sample Sizes:				
	156	188		

Note: Differences between sample sizes for VEH types in the top table and the bottom table (62+92≠156, etc.) are due to missing data on TGTMOT in a few cases.

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